Performance Evaluation of a UWB-RFID System for Potential Space Applications

Abstract

This talk presents a brief overview of the ultra-wideband (UWB) RFID system with emphasis on the performance evaluation of a commercially available UWB-RFID system. There are many RFID systems available today, but many provide just basic identification for auditing and inventory tracking. For applications that require high precision real time tracking, UWB technology has been shown to be a viable solution. The use of extremely short bursts of RF pulses offers high immunity to interference from other RF systems, precise tracking due to sub-nanosecond time resolution, and robust performance in multipath environments.

The UWB-RFID system Sapphire DART (Digital Active RFID & Tracking) will be introduced in this talk. Laboratory testing using Sapphire DART is performed to evaluate its capability such as coverage area, accuracy, ease of operation, and robustness. Performance evaluation of this system in an operational environment (a receiving warehouse) for inventory tracking is also conducted. Concepts of using the UWB-RFID technology to track astronauts and assets are being proposed for space exploration.

Performance Evaluation of a UWB-RFID System for Potential Space Applications

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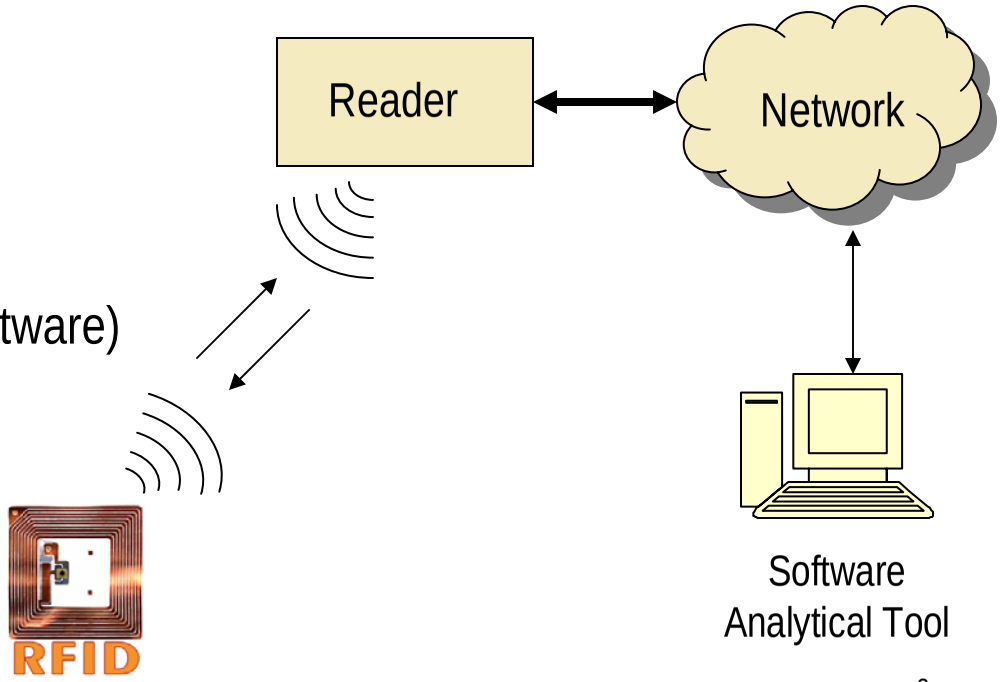
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Outline

- RFID Technology Overview
- UWB-RFID Technology
- Sapphire DART Overview
- Laboratory Testing of Sapphire DART
- Warehouse Testing of Sapphire DART
- Potential Space Applications

RFID Technology Overview

- Radio Frequency Identification: a technology of identifying people or objects remotely using radio frequency signals.
- Capabilities: vary greatly from simple presence detection to high precision location tracking
- Basic Components:
  - Tags (chip and antenna)
  - Readers/receivers
  - Network (database and software)



RFID Tags

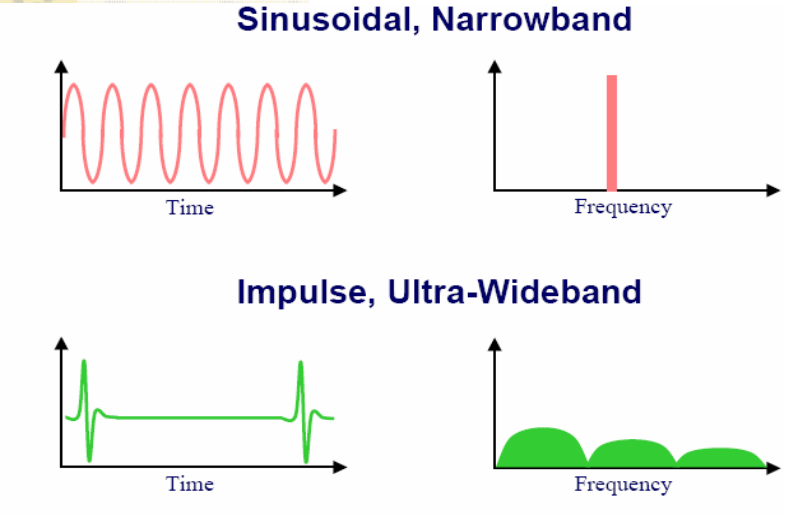
- Passive Tags
  - No on-board power source
  - Reader initiates communication via RF signal that is strong enough to energize the tag
  - Tag sends its unique information back to the reader
  - Simple, small, long life, and inexpensive
  - Low transfer data rates
  - Short reading distance of typically a few feet
- Active Tags
  - Battery powered; operational life depends on operating temperature and update rate
  - Can send its unique identifier along with other sensor data such as temperature to the reader
  - Higher transfer data rates
  - Reading distance can be 100 ft or more

RFID Frequencies

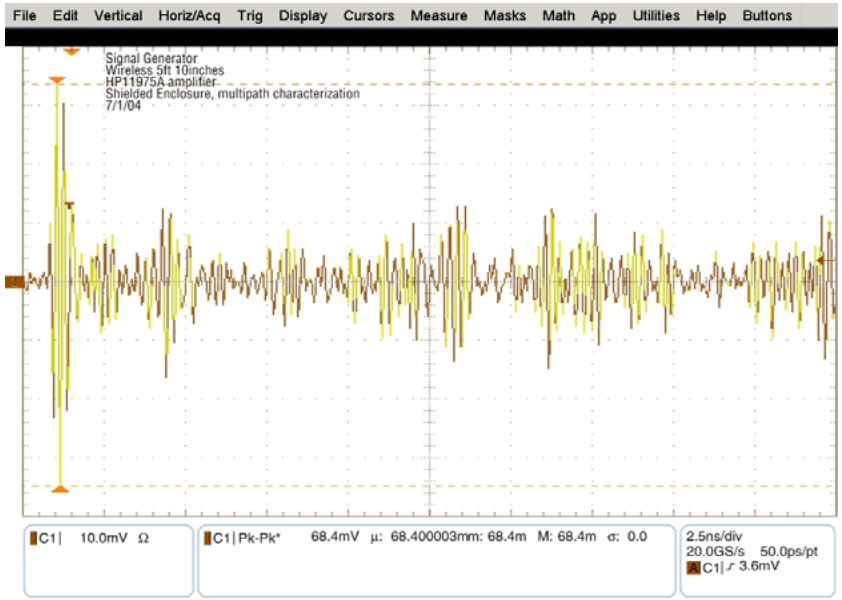
- Lower Frequencies (125 – 134 KHz or 13.56 MHz)
  - Generally passive tags
  - Good performance in the presence of metals and liquids
  - Basic detection of tag only, no location
- Higher Frequencies (315 - 930 MHz, 2.45 GHz, and 5.8 GHz)
  - Active or passive tags
  - More susceptible to multipath distortion (scattering, reflection, diffraction)
  - Track location of tag but accuracy is limited to approximately 5 ft
- Ultra-Wide Band (3.1-10.6 GHz)
  - Active tags
  - Robust performance in multipath environments
  - Track location of tag with high accuracy from within an inch to 1 ft

UWB Features

- Immunity to interference from narrow band RF systems due to ultra-wide bandwidth
- Low impact on other RF systems due to extremely low power spectral densities
- Capable of precise tracking due to sub-nanosecond time resolution
- Robust performance in multipath environments



UWB Fine Time Resolution

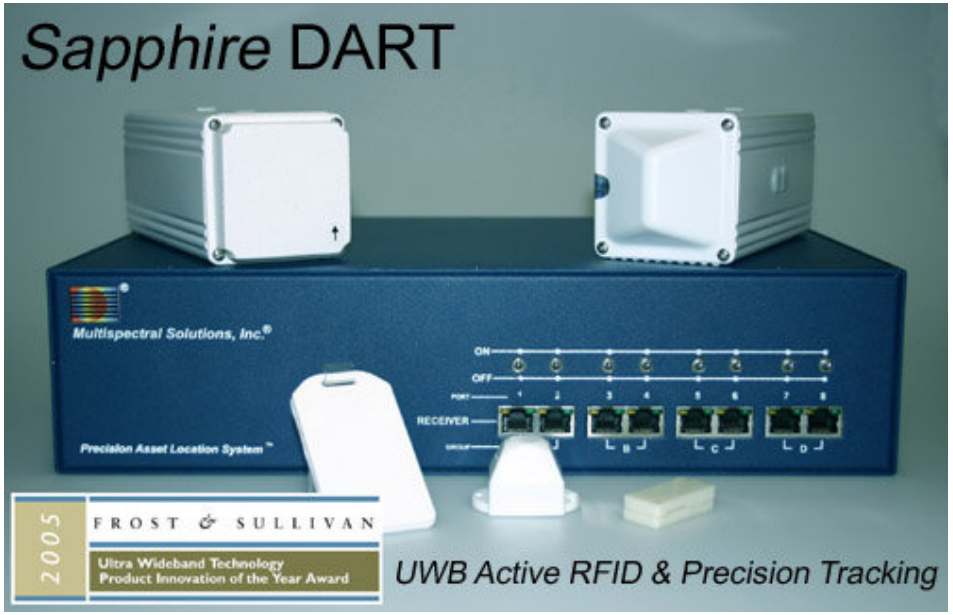


Resolving between direct vs. multipath components is possible with extremely narrow UWB pulses

UWB-RFID Technology

- UWB-RFID is designed to track people and high-value assets where high accuracy is required
- System works by creating “cells” throughout facilities or factories. Each cell requires a minimum of 4 receivers that are networked together. Information from all cells are integrated to form a database
- Synchronization among current commercial receivers within a cell is 1 nsec (limits tracking accuracy to 1 ft)
- Tracking technique is based on TDOA (time difference of arrival) or TDOA combined with AOA (angle of arrival)

Sapphire DART (Digital Active RFID & Tracking) Overview



Vendor Specifications:

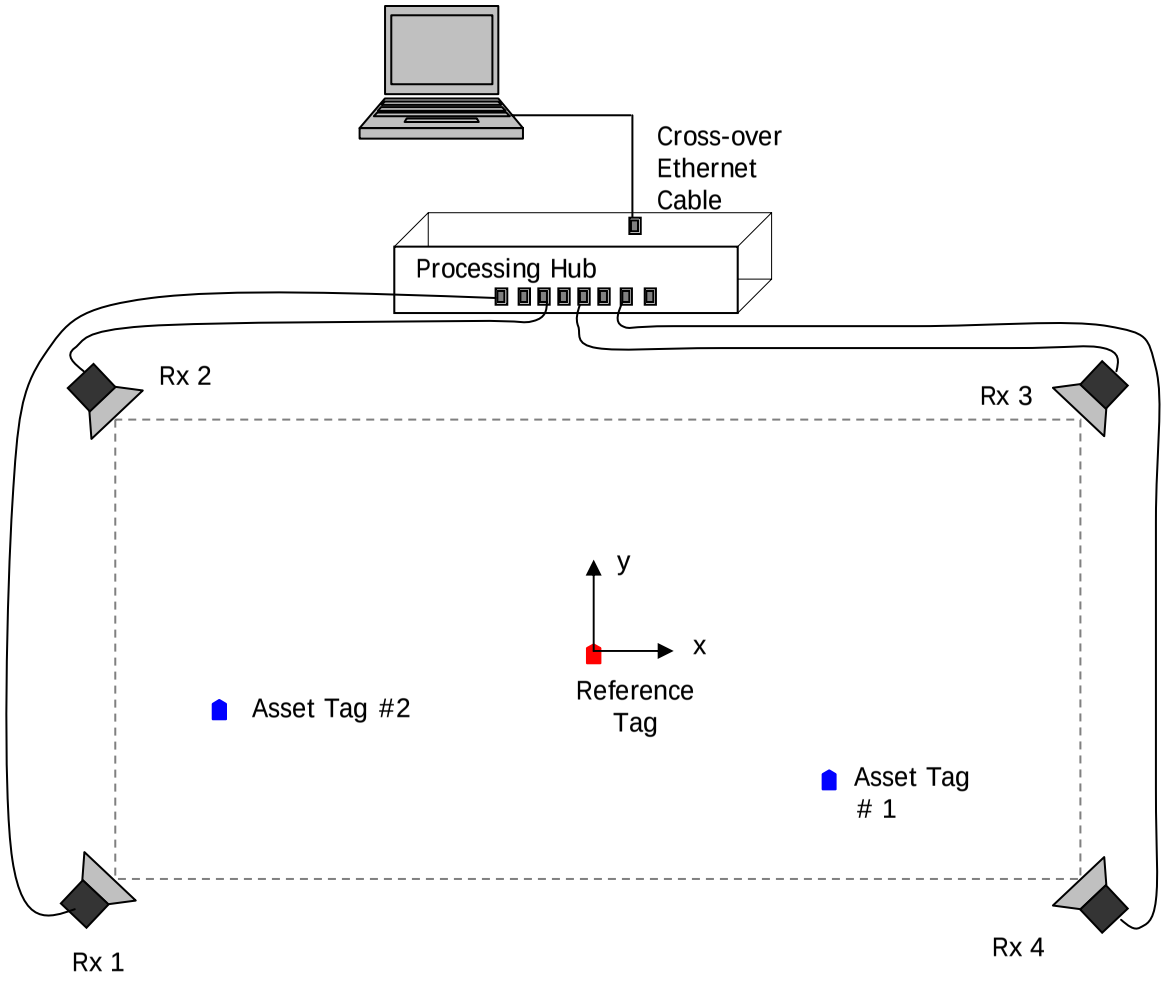
- Frequency: 5.94 to 7.12 GHz
- Accuracy: within +/- 1 foot
- Tag battery life: in excess of 4 years (1 Hz rate)
- Tag read range: up to 160 ft indoors
- Hub is configurable to accommodate various configurations/coverages

Sapphire DART Evaluation Kit PAL651-EK

- Evaluation kit:
  - One processing hub
  - Four receivers, each with its own antenna
  - Eleven tags, one for use as a reference tag
  - Four 150 ft CAT 5E cables
  - Management software and documentation

- Tracking technique:
  - Short burst of pulses transmitted by the active tags are received by receivers located at the periphery of the desired coverage area
  - One tag is designated as a reference tag and is used for automatic system calibration and synchronization
  - Location of asset tags is based on the time differences of the signal arriving at multiple receivers (TDOA technique)
  - Accurate and reliable 2D TDOA tracking requires at least 4 receivers (3D will require at least 5 receivers)

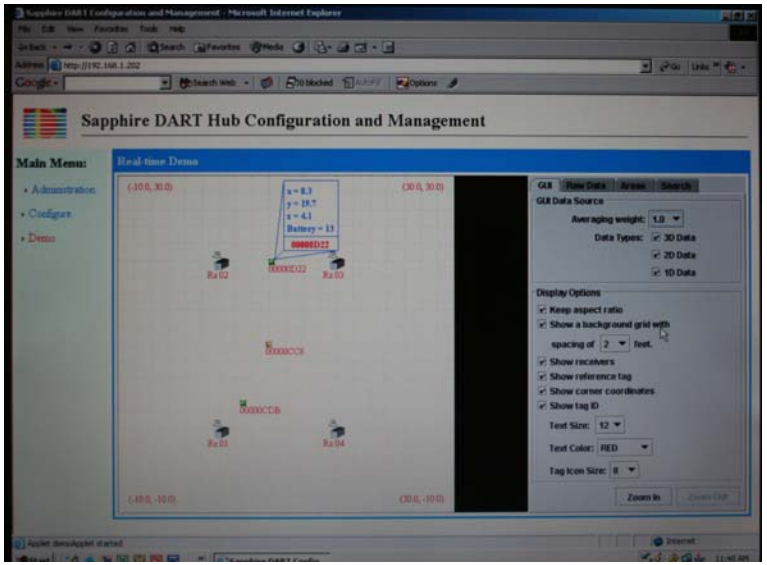
Laboratory Testing of Sapphire DART PAL651-EK



Laboratory Testing Results

- Performance in laboratory environment
  - Coverage: minimum tested area is 12’ x 12’ (vendor specifies 20’ x 20’)
  - Accuracy: within specification (+/- 1 foot)
  - Robustness: tracking performance is within specification in a multipath environment (near metallic objects or inside ESD bags)





Warehouse Testing of Sapphire DART PAL651-EK

- A section of approximately 25 ft x 150 ft in the back of building 421 receiving warehouse is being used to evaluate the performance of RFID tracking (2 aisles of storage goods and equipment stacked on metal shelves)
- Initial results show performance is within specification when test area is square (x and y dimensions are approximately equal) but errors are large if one dimension is longer



Conclusions

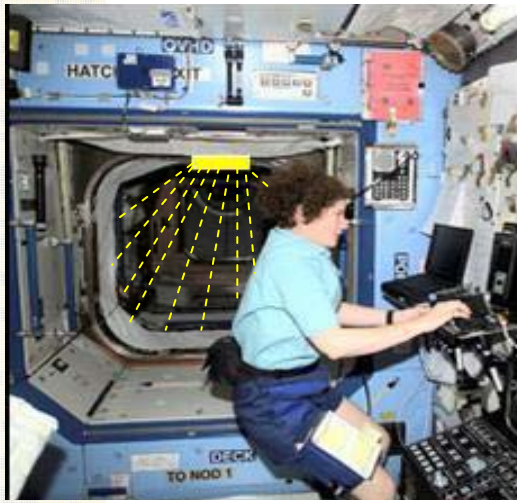
- The tests conducted to date have provided useful information on the capability of commercial UWB-RFID products
- Except in limited test configurations, the Sapphire DART system does not appear to have the accuracy within 1 ft as claimed by the vendor's specifications
- Synchronization among multiple receivers needs to be less than 1 nsec to achieve the tracking resolution better than 1 ft
- One technique to overcome this synchronization problem is to use 1 receiver with a cluster of antennas developed at JSC. Tracking accuracy can be improved to sub-inch level using JSC derived technique

Future Work

- Sapphire DART System
  - Investigate effects of unequal dimensions on tracking performance
  - Extend the tracking dimension from 2D to 3D with additional receivers
  - Extend the coverage area with additional receivers
  - Extract raw data to improve accuracy and optimize performance
  - Adding user-defined graphics to map the operational environment
  - Integrate UWB-RFID tags with additional sensors such as temperature or pressure
- JSC/UWB-RFID using TDOA Tracking System
  - Perform additional simulation and testing to determine the capability of JSC tracking technique for RFID applications

Potential Space Applications

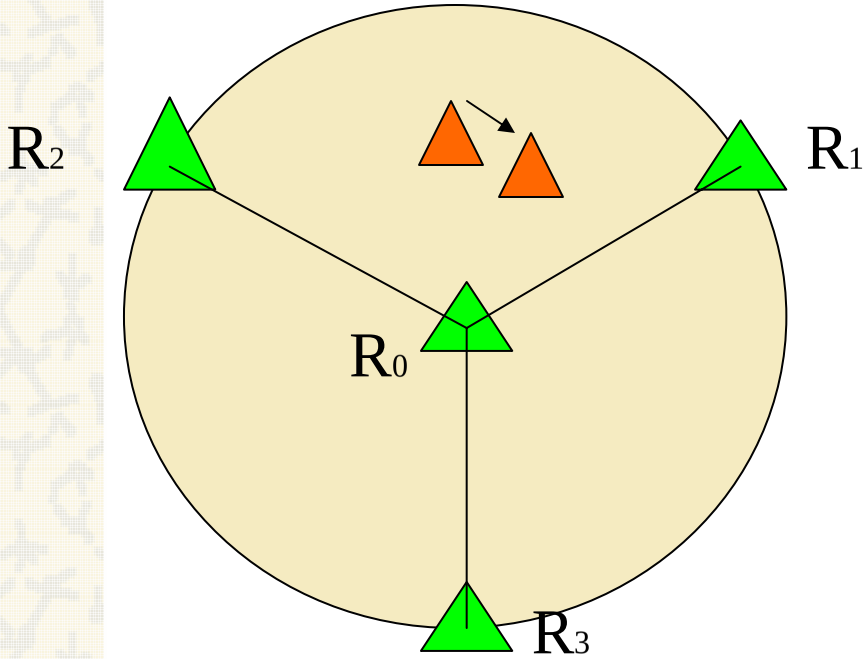
- Complement the Inventory Management System (barcode data manually scanned which is time consuming and labor intensive) on the International Space Station to improve asset tracking
  - Capable of automated precise **location** tracking (unlike other inventory systems)
  - Track items that are being moved between bags, racks, or shelves





Potential Space Applications

- Location sensing for Robonaut applications
  - Lab experiment has shown accuracy to within an inch can be achieved using the JSC/TDOA short range technique





Potential Space Applications

- Astronaut Tracking for Lunar Surface Exploration Using UWB-RFID Technology

